A Study on the Specific Combining Ability in Several Inbred Lines of Maize

10.18196/pt.v11i2.14026

Heri Kustanto[1]* and Febri Hendrayana[2]

[1]*Faculty of Agriculture, Universitas Wahid Hasyim, Jl. Menoreh Tengah X / 22, Sampangan, Gajahmungkur, Semarang, Central Java 50232, Indonesia.*

[2]*Faculty of Agriculture, Kahuripan University of Kediri, Jl. Soekarno Hatta, Ngeblek, Pelem, Pare, Kediri, East Java 64213, Indonesia.*

**Corresponding author, email:* heri.kustanto@unwahas.ac.id

ABSTRACT

Maize is a cereal crop essential to fulfill the need for food and support global food security programs. Maize hybrid varieties play a very significant role in increasing maize production. Objectives of the research were to obtain a tester, which is consistent in identifying inbred lines with a high specific combining ability, and to obtain prospective crossed-hybrids that have the potential assembling to be maize hybrid varieties. The grain yield showed that the specific combining ability values ranged from -3682.2 to 5251.7. Crosses that have high and positive specific combining ability included lines of JG-11, JG-18, JG-34, JG-01, JG-40, JG-B0, JG-19, and JG-02 with a tester of JG-T00; lines of JG-20, JG-01, JG-03, JG-42, JG-02, JG-46, and tester of JG-T14; lines of JG-24, JG-08, JG-23, JG-26, JG-21, JG-07, and JG-06 with a tester of JG-T15; lines of JG-38, JG-40, JG-35, JG-36, JG-01, JG-51, JG-17, JG-B0, and JG-08 with tester of JG-T22; and lines of JG-07, JG-01, JG-26, JG-24, and JG-18 with tester of JG-T37. There were combinations of 9 crosses between inbred lines and the best testers, including JG-06XJG-T15, JG-51XJG-T22, JG-49XJG-T22, JG-B0XJG-T22, JG-35XJG-T22, JG-38XJG-T22, JG-17XJG-T22, JG-36XJG-T22, and JG-49XJG-37, which are potential as prospective maize hybrids that have high productivity.

Keywords: Analysis; Hybrid; Line; Maize; Tester

ABSTRAK

Jagung (Zea Mays L.) merupakan tanaman serealia yang sangat penting untuk memenuhi kebutuhan pangan dan mendukung program ketahanan pangan global. Varietas jagung hibrida sangat berperan dalam peningkatan produksi jagung. Tujuan penelitian ini adalah untuk mendapatkan penguji yang konsisten dalam mengidentifikasi galur inbrida yang memiliki daya gabung khusus yang tinggi dan mendapatkan calon hibrida yang memiliki sifat unggul, dan mendapatkan penguji yang konsisten dalam mengidentifikasi galur inbrida yang memiliki daya gabung khusus yang tinggi. Hasil pipilan kering menunjukkan bahwa nilai daya gabung khusus berkisar antara -3682,2 sampai 5251,7. Persilangan yang memiliki daya gabung khusus tinggi dan bernilai positif antara lain galur inbrida sebagai berikut: JG-11, JG-18, JG-34, JG-01, JG-40, JG-B0, JG-19, JG-02 dan penguji JG- T00; galur inbrida: JG-20, JG-01, JG-03, JG-42, JG-02, JG-46 dan penguji JG-T14; galur inbrida: JG-24, JG-08, JG-23, JG-26, JG-21, JG-07, dan JG-06 dengan penguji JG-T15; galur inbrida: JG-38, JG-40, JG-35, JG-36, JG-01, JG-51, JG-17, JG-B0, JG-08 dan penguji JG-T22; galur inbrida: JG-07, JG-01, JG-26, JG-24 dan JG-18 dengan penguji JG-T37. Terdapat kombinasi 9 persilangan antar galur inbrida dan penguji terbaik, seperti: JG-06XJG-T15, JG-51XJG-T22, JG-49XJG-T22, JG-B0XJG-T22, JG-35XJG-T22, JG-38XJG-T22, JG-17XJG-T22, JG-36XJG-T22, dan JG-49XJG-37, yang berpotensi sebagai calon hibrida jagung yang memiliki produktivitas tinggi.

Kata kunci: *Analisis; Hibrida; Lini; Jagung; Penguji*

INTRODUCTION

Corn breeding aims to develop superior hybrid variants. The first step involves germplasm collection, which should possess the high genetic variability necessary for establishing new inbred lines. Subsequently, genetic engineering, selection, and identification of new superior inbred lines are carried out through molecular marker analysis and testcross. The following steps include establishing new superior hybrids based on diallel analysis and multi-location tests to determine hybrid stability and adaptability to specific environments, followed by hybrid release and commercialization (Gedil & Menkir, 2019).

Maize breeding has faced some problems and obstacles that must be solved. Besides limited genetic resources, hybrid maize breeding requires

Article History
Received: 18 February 2022
Accepted: 8 August 2023

much time. The process was made by preparing inbred lines and testing their combining abilities. Estimating the combining ability is very important in hybridization breeding to obtain crosses with a high combining ability (Ali et al., 2019; de Faria et al., 2022). Combining ability comprises general combining ability (GCA) and Specific Combining Ability (SCA). General combining ability (GCA) relates to the parent and results from the additive gene's effect. Specific combining ability results from non-additive gene effects, such as dominance, epistasis, and the impact of genotype x environment (Sprague & Tatum, 1942; Yadesa et al., 2021).

The combining ability test was done through diallel crosses by establishing cross combinations among the available inbred lines. The significant number of inbred lines requires more cross combination, causing the method to be ineffective because the number of inbred lines is very high. To overcome the problem, it needs a test cross by crossing the inbred lines and the tester. The tester's parents are identical for each inbred line, so each inbred line may only have one crossing. The potency for many inbred lines may be tested by testcross. Tester can also be used to determine the genetic variability of the emerged inbred lines on the result of the crosses (Murtadha et al., 2018).

The technique, which has been used by the maize breeders in selecting parents of the inbred lines, is through testcross by testing the general combining ability (GCA) and specific combining ability (SCA). The combining ability is the relative ability of an inbred line crossed with other inbred lines to produce excellent traits as desired. Information on general combining ability (GCA) plays a significant role in evaluating the inbred lines. In contrast, the specific combining ability (SCA) plays a role in determining the best crosses on maize hybrid development. The identified populations with excellent General Combining Ability may have a chance to produce high specific combining ability (Choudhary et al., 2018; Murtadha et al., 2018).

Line × tester mating scheme is an effective method to estimate general (GCA) and specific (SCA), combining ability effects and recognizing the appropriate parents (Kamara et al., 2021). The combining ability of inbred lines of maize and the classification of inbred lines provide information on their usefulness for developing productive hybrids. The potential of inbred lines to hybridize is passed on to their progenies and is referred to as combining ability. Studies on combining abilities are invaluable for designing hybrid breeding programs and comparing the performance of hybrids derived from inbred lines. Information on the combining ability of inbred lines in hybrid combinations is necessary for a successful maize hybrid improvement (Oluwaseun et al., 2022). Evaluation of early-generation inbred progenies in testcross has been the primary method in maize breeding for developing inbred lines (Ur Rehman et al., 2018).

General combining ability (GCA) and specific combining ability (SCA) may have positive and negative effects. Positive means that the inbred lines or the hybrids are better than the negative ones (even have the same traits), while negative means that the inbred lines or the hybrids, with the same characteristics, are inadequate in comparison with the positive ones (Karim et al., 2018; Natol, 2017; Rani et al., 2018). The problem in assembling maize hybrid varieties is the proper selection of inbred lines. The selected inbred line should be a hybrid cross pair with superior characteristics such as high yielding. The assembly of superior varieties of hybrid maize is mainly determined by a selection of inbred lines used to be parents. Information on a specific combining ability is used to select suitable inbred lines for creating hybrid varieties. This research aimed to estimate general combining ability (GCA) and specific combining ability (SCA) and to obtain prospective hybrids that could assemble new varieties. The specific combining ability (SCA) testing is used to identify pairs of inbred lines capable of producing the best hybrid varieties. Another objective was identifying inbred lines that could produce a superior hybrid when crossed with other inbred lines.

MATERIALS AND METHODS

Inbred Lines Selection

Inbred line in the experiments selected from 140 F1 crosses, 28 lines, and 5 testers, and derived from open pollination for 2 seasons among several original maize local and commercial varieties in Indonesia. Genotype S1 was derived from selfing and sibling mating from a primary population. Genotype S2 was derived from selfing and sibling mating from genotype S1 up to a generation of genotype S6, derived from selfing and sibling mating from genotype S5. In the generation of genotype-6 (S6), 33 inbred lines were selected, which were used in the research. Inbred lines that were used include JG-01, JG-02, JG-03, JG-04, JG-05, JG-06, JG-08, JG-11, JG-13, JG-14, JG-15, JG-17, JG-18, JG-19, JG-20, JG-21, JG-23, JG-24, JG-26, JG-34, JG-35, JG-36, JG-38, JG-40, JG-42, JG-44, JG-46, JG-49, JG-51, JG-BO, and inbred lines that were used as testers, including JG-T00, JG-T14, JG-T15, JG-T22, and JG-T37.

Experimental Design

The experiment was conducted from July to November 2017 at Kandangan, Kediri, East Java. The experiment was done by planting F1 (crosses), 28 lines, and 5 testers arranged in a Randomized Block Design (RBD) with 2 replications. The spacing used was 75 cm x 20 cm. The 1st fertilization was given at 0 DAP (days after planting) with a 100 kg NPK/Ha. The 2nd fertilization was given at 21 DAP with 100 kg NPK/Ha and 50 kg Urea/kg. The 3rd fertilization was given at 45 DAP with 100 kg NPK/Ha and 50 kg Urea/kg dose. Weeding and hilling were done simultaneously with the second and third fertilization manually. Irrigation

Table 1. The observed traits

Traits	Observation
Plant high (cm)	measured from the soil surface to the base of the panicle (flag leaf), which was carried out after the kernel milk stage
Ear height (cm)	measured from the soil surface to the base of the panicle, which was carried out after kernel milk stage.
Width leaf (cm)	measured at the middle of the leaf under the ear
Tassel length (cm)	measured from the flag leaf to the tip of the panicle
Days to tasseling (dap)	counting the day of tassels come out, days after planting
Days to silking (dap)	counting the day silks come out
Days of maturity (dap)	counting the number of days of the plant is ready to be harvested with an indication that ears have dried up
Corn husk weight plant^{-1} (kg)	scaling the weight of cornhusk per ear
Weight of wet ear plant^{-1} (kg)	scaling the weight of ears after peeling
Grain yield plant^{-1} (kg)	scaling the weight of kernel per plant
Ear diameter (cm)	measure the center of ear using a caliper
Ear length (cm)	measure the length from base to tip ear
Number of rows ear^{-1}	counting the number of rows per ear
number of kernel row^{-1}	counting the number of kernels per row
Moisture content (%)	measure the moisture content on wet kernels with a corn moisture tester
Weight of 100 kernels (g)	scaling the weight of 100 wet kernels
Grain yield (kg/ha)	counting the grain plot then conversion yield per ha

was done 7 times, starting at 10 DAP of age and every interval of 10 DAP. Pest control was carried out using *emamectin benzoate* at 100 g ha -1.

The observed traits (Jahangirlou et al., 2021; Kartahadimaja & Syuriani, 2021) are presented in Table 1.

Data Analysis

Data of the observation results on the whole tested genotypes were analyzed using analysis of variance. The linear additive model of the RCBD is as follows:

$$X_{ijkl} = \mu + g_{ijk} + b_l + {}_{ijkl}, \quad (1)$$

Remarks:

X_{ijkl} = value of the observed traits at the-*ijk* genotype, the 1st group,

μ = effect of the median value of the population from the observed traits

g_{ijk}= effect of the-*ijk* genotype on the observed traits,

b_l= effect of the 1st group on the observed traits

$\sum_{ijkl}$= effect of the experimental error on the-*ijk* genotype at the-*i* group.

An F-test was conducted to study the effect of genotype. Analysis of Line x Tester used quantitative genetic analysis by SCA criteria as follows: (1) positive and high if SCA is positive and equals/more than one of its standard error, (2) negative and high if SCA is negative and equals/more than one of its standard error, (3) positive and low if SCA is positive and less than once of its standard error, and (4) negative and low if SCA is negative and less than once of its standard error (Akula et al., 2016; Bhusal & Lal, 2020; Natol, 2017; Rani et al., 2018; Yadesa et al., 2021).

RESULTS AND DISCUSSION

Line x Tester Analyzed

Combined analysis of variance against the observed traits showed that the traits, including plant height, ear height, leaf length, tassel length, days to tassel, days to silking, days of maturity, the weight of wet ear plant^{-1}, the weight of wet kernel plant^{-1}, ear diameter, ear length, number of rows ear^{-1}, number of kernels row^{-1}, moisture content, the weight of 100 kernels and grain yield, showed significant differences among the tested genotypes on F-test at level 5%. Meanwhile, leaf width and cornhusk weight plant^{-1} showed insignificant differences among the tested genotypes by the F-test at level p= 0.05. It indicated that the used populations have significant genetic variability. Results of the F-test at level p=0.05 showed that all observed traits, except leaf width and cornhusk weight plant^{-1}, had significant differences (Table 2).

Based on the parent x-tester analysis, partition against the genotype component in the next component can be done if the genotype has a significant effect. Partition of the genotype component into the parent crosses, and the parent x crosses are presented in Table 3. Table 3 shows that the parent component significantly affects all observed traits except the cornhusk-weight plant^{-1}. The cross components significantly affect almost all traits except leaf length, leaf width, cornhusk weight plant^{-1}, and weight of 100 kernels. Meanwhile, the parent x cross-component significantly affects almost all traits except leaf width, cornhusk weight plant^{-1}, and moisture content during harvest time. The results of the analysis of variance on cross-component partition into lines, tester, and lines x testers are presented in Table 4.

Table 3 shows that the line component significantly affects all of the observed traits except leaf width, cornhusk weight plant^{-1}, and weight of 100 kernels. The tester component shows a significant effect on all traits of the plant except leaf length, and the component of line x tester shows a signifi-

Table 2. Mean Square and F-count from Randomized Block Design (RBD) for the observed traits

	MS			F-count			
Traits	r	t	e	R		t	
DF	1	172	172	1		172	
PH	60.0	663.7	159.0	0.4	Ns	4.2	*
EH	214.5	442.1	97.2	2.2	Ns	4.5	*
LL	174.9	115.8	87.7	2.0	Ns	1.3	*
LW	4.8	1.0	0.9	5.3	*	1.1	ns
TL	36.8	29.6	8.5	4.3	*	3.5	*
DA	0.3	32.5	1.5	0.2	ns	21.5	*
DS	0.3	33.7	4.0	0.1	ns	8.4	*
DM	0.1	49.3	9.7	0.01	ns	5.1	*
CW	5.1	0.0	0.0	0.01	ns	0.5	ns
WC	0.0	0.0	0.0	39.8	*	9.0	*
WK	0.0	0.0	0.0	39.3	*	8.4	*
CB	0.0	0.2	0.1	0.4	ns	2.4	*
CL	18.9	5.6	1.1	17.1	*	5.1	*
NR	0.3	3.3	1.0	0.3	ns	3.2	*
NK	87.4	26.2	8.7	10.0	*	3.0	*
MC	0.3	4.5	2.5	0.1	ns	1.8	*
WK	0.0	0.0	0.0	18.5	*	1.6	*
GY	18033219.8	11934357.1	1144547.7	15.8	*	10.4	*

Remarks: MS: Mean Square, DF: Degree of freedom, r: replication, t: genotype, e: error, ns= Non significance at p=0.05 level; *: Significance at p= 0.05 level. PH: Plant height, EH: Ear height (cm), LL: Leaf length (cm), LW: Leaf width (cm), TL: Tassel length (cm), DA: Days to tasseling, DS: Days to silking , DM: Days of maturity, CW: Cornhusk weight (kg) plant^{-1}, WC: Weight of wet ear (kg) plant^{-1}, WK: Weight of wet kernel (kg) plant^{-1}, CB: Ear diameter (cm), CL: Ear length (cm), NR: Number of rows ear^{-1}, NK: Number of kernel row^{-1}, MC: Moisture content (%),WK: Weight of 100 kernels and GY: Grain Yield (kg/ha)

Table 3. Mean Square Values and F-count of Genotype Treatment Partition into Parent x Crosses for the observed traits

	Mean square			**F-count**					
Traits	**P**	**C**	**PXC**	**P**	**C**	**PxC**		**TxP**	
DF	**32**	**139**	**1**	**32**		**139**		**1**	
PH	**545.4**	**421.9**	**38045.2**	**3.4**	*	**2.7**	*	**239.3**	*
EH	**577.4**	**332.8**	**11305.9**	**5.9**	*	**3.4**	*	**116.3**	*
LL	**195.1**	**76.1**	**3107.5**	**2.2**	*	**0.9**	**ns**	**35.4**	*
LW	**1.7**	**0.8**	**0.3**	**1.9**	*	**0.9**	**ns**	**0.3**	**ns**
TL	**54.1**	**21.5**	**369.7**	**6.3**	*	**2.5**	*	**43.3**	*
DA	**55.9**	**26.2**	**153.5**	**37.0**	*	**17.4**	*	**101.5**	*
DS	**75.8**	**23.3**	**129.4**	**18.8**	*	**5.8**	*	**32.1**	*
DM	**57.5**	**46.6**	**174.3**	**5.9**	*	**4.8**	*	**18.0**	*
CW	**0.0**	**0.0**	**0.0**	**0.9**	**ns**	**0.4**	**ns**	**2.3**	**ns**
WC	**0.0**	**0.0**	**0.2**	**4.1**	*	**5.8**	*	**605.6**	*
WK	**0.0**	**0.0**	**0.2**	**3.8**	*	**4.8**	*	**657.1**	*
CB	**0.2**	**0.1**	**8.6**	**2.4**	*	**1.7**	*	**101.3**	*
CL	**2.8**	**4.2**	**303.7**	**2.5**	*	**3.8**	*	**274.6**	*
NR	**4.0**	**3.1**	**4.0**	**3.8**	*	**3.0**	*	**3.9**	*
NK	**31.2**	**19.4**	**813.1**	**3.6**	*	**2.2**	*	**92.9**	*
MC	**7.5**	**3.8**	**7.4**	**3.0**	*	**1.5**	*	**2.9**	**ns**
WK	**0.0**	**0.0**	**0.0**	**2.0**	*	**1.2**	**ns**	**49.9**	*
GY	**7485856.5**	**5352512.1**	**1069162835.3**	**6.5**	*	**4.7**	*	**934.1**	*

Remarks: P= parent, C= Crosses, Df: Degree of freedom, r: replication, t: genotype, e: error, ns= Non significance at p=0.05 level; *: Significance at p= 0.05 level. PH: Plant height, EH: Ear height, LL: Leaf length, LW: Leaf width, TL: Tassel length, DA: Days to tasseling, DS: Days to silking, DM: Days of maturity, CW: Cornhusk weight plant^{-1}, WC: Weight of wet ear plant^{-1}, WK: Weight of wet kernel plant^{-1}, CB: Ear diameter, CL: Ear length, NR: Number of rows ear^{-1}, NK: Number of kernel row^{-1}, MC: Moisture content, WK: Weight of 100 kernels and GY: Grain Yield

Table 4. Mean Square Values and F-count on Analysis of Line x Tester for observed traits

Traits	Mean square			F-count					
	Line	Tester	LxT	Line		Tester		LxT	
DF	27	4	108	27		4		108	
PH	331.9	6546.6	159.0	2.1	*	41.2	*	1.4	*
EH	273.4	5280.5	164.4	2.8	*	54.3	*	1.7	*
LL	147.0	148.3	55.6	1.7	*	1.7	ns	0.6	ns
LW	1.0	4.8	0.6	1.0	Ns	5.2	ns	0.7	ns
TL	45.8	74.9	13.5	5.4	*	8.8	*	1.6	*
DA	47.2	392.3	7.4	31.2	*	259.5	*	4.9	*
DS	40.2	347.7	7.0	10.0	*	86.3	*	1.7	*
DM	101.3	373.4	20.8	10.5	*	38.6	*	2.1	*
CW	0.0	0.0	0.0	0.4	Ns	3.2	ns	0.3	ns
WC	0.0	0.0	0.0	4.8	*	116.0	*	1.9	*
WK	0.0	0.0	0.0	4.1	*	93.6	*	1.7	*
CB	0.2	1.1	0.1	1.9	*	12.6	*	1.3	*
CL	5.2	51.5	2.1	4.7	*	46.6	*	1.9	*
NR	5.3	22.2	1.9	5.1	*	21.5	*	1.8	*
NK	29.9	155.9	11.7	3.4	*	17.8	*	1.3	*
MC	6.5	28.8	2.2	2.6	*	11.5	*	0.9	ns
WK	0.0	0.0	0.0	1.5	Ns	4.7	ns	1.0	ns
GY	6538253.8	33150531.4	4026520.4	5.7	*	29.0	*	3.5	*

Remarks: DF: Degree of freedom, LxT: line x tester, ns= Non significance on F-test at p=0.05 level, *: different on F-test at level 5%, PH: Plant height, EH: Ear height, LL: Leaf length, LW: Leaf width, TL: Tassel length, DA: Days to tasseling, DS: Days to silking , DM: Days of maturity, CW: Cornhusk weight plant^{-1}, WC: Weight of wet ear plant^{-1}, WK: Weight of wet kernel plant^{-1}, CB: Ear diameter, CL: Ear length, NR: Number of rows ear^{-1}, NK: Number of kernel row^{-1}, MC: Moisture content, WK: Weight of 100 kernels and GY: Grain Yield

cant interaction effect on almost all traits except leaf length, leaf width, cornhusk weight plant^{-1}, the moisture content in harvest time, and weight of 100 kernels.

A specific combining ability and Prospective Crossed-Hybrids

The Specific combining ability (SCA) comprises positive and negative values. The analysis results on the specific combining ability (SCA) effect showed differences among the observed crosses and traits. The specific combining ability (SCA) values on grain yield are presented in Table 5.

The specific combining ability in grain yield ranged from -3682.2 to 5251.7. There were combinations for 9 crosses between inbred lines and the best testers, consisting of JG-06XJG-T15, JG-51XJG-T22, JG-49XJG-T22, JG-B0XJG-T22, JG-35XJG-T22, JG-38XJG-T22, JG-17XJG-T22, JG-36XJG-T22, and JG-49XJG-37, found to be potential as prospective hybrid varieties that have high productivity. Crosses that have positive and high specific combining ability were lines of JG-11, JG-18, JG-34, JG-01, JG-40, JG-B0, JG-19, JG-02 and the tester JG-T00; lines: JG-20, JG-01, JG-03, JG-42, JG-02, and JG-46 with tester of JG-T14; lines of JG-24, JG-08, JG-23, JG-26, JG-21, JG-07, and JG-06 with tester of JG-T15; lines of JG-38, JG-40, JG-35, JG-36, JG-01, JG-51, JG-17, JG-B0, and JG-08 with tester of JG-T22; lines of JG-07, JG-01, JG-26, JG-24, and JG-18 with tester of JG-T37. The grain yield showed negative and high specific combining ability on crosses of lines of JG-36, JG-44, JG-08, JG-06, JG-46, and JG-01 with a tester of JG-T00; lines of JG-18, JG-B0, JG-26, JG-35, JG-24, JG-08, JG-36, JG-23 and JG-17 with a tester of JG-T14; lines of JG-49, JG-44, JG-11, JG-04, JG-03, and JG-02 with a tester of JG-T15; lines of JG-20, JG-18, JG-24, JG-19, JG-26, JG-21, JG-42, and JG-07 with tester of JG-T22; and lines of JG-19, JG-06,

Table 5. Specific Combining Ability Values of the Grain Yield (kg ha-1)

Specific Combining Ability (SCA)									
Grain Yield									
L	T	L	T	L	T	L	T	L	T
	JG-T00		JG-T14		JG-T15		JG-T22		JG-T37
JG-02	2388.0	JG-46	5251.7	JG-06	2910.2	JG-08	2162.0	JG-18	1440.2
JG-19	2202.9	JG-02	1617.3	JG-07	1710.3	JG-B0	1938.2	JG-24	1275.6
JG-B0	1722.2	JG-42	1411.5	JG-21	1594.8	JG-17	1898.3	JG-26	1036.7
JG-40	1107.1	JG-03	1188.0	JG-26	1256.6	JG-51	1631.0	JG-01	768.6
JG-04	1065.2	JG-01	1026.3	JG-23	1159.6	JG-01	1522.9	JG-07	744.2
JG-34	831.4	JG-20	887.2	JG-08	976.9	JG-36	1488.3	JG-20	710.6
JG-18	808.6	JG-07	739.4	JG-24	938.2	JG-35	1429.8	JG-49	706.5
JG-11	788.7	JG-13	697.1	JG-35	752.4	JG-40	981.8	JG-17	627.6
JG-13	664.4	JG-44	580.7	JG-36	639.8	JG-38	883.4	JG-44	616.8
JG-26	381.1	JG-21	505.0	JG-38	290.9	JG-44	581.3	JG-23	507.3
JG-23	295.2	JG-38	413.5	JG-42	247.8	JG-04	534.7	JG-03	482.3
JG-42	294.5	JG-11	106.9	JG-13	162.6	JG-03	506.3	JG-11	432.7
JG-24	264.1	JG-19	75.7	JG-34	-6.0	JG-49	386.6	JG-04	401.9
JG-21	-28.4	JG-06	-103.5	JG-17	-39.5	JG-13	127.9	JG-51	396.4
JG-49	-53.4	JG-49	-182.1	JG-19	-105.9	JG-23	58.0	JG-02	270.2
JG-17	-138.7	JG-04	-332.8	JG-20	-182.3	JG-11	-301.8	JG-42	248.9
JG-38	-299.3	JG-34	-412.1	JG-B0	-249.5	JG-34	-367.6	JG-21	112.1
JG-03	-325.9	JG-40	-603.1	JG-01	-283.0	JG-02	-593.3	JG-36	109.5
JG-20	-360.9	JG-18	-709.0	JG-46	-354.4	JG-06	-675.7	JG-34	-45.7
JG-07	-451.6	JG-51	-778.9	JG-18	-407.2	JG-46	-695.9	JG-35	-516.6
JG-35	-569.1	JG-B0	-871.1	JG-51	-505.0	JG-20	-1054.6	JG-08	-655.0
JG-51	-743.4	JG-26	-1001.1	JG-40	-547.4	JG-18	-1132.7	JG-19	-868.6
JG-36	-767.9	JG-35	-1096.5	JG-49	-857.6	JG-24	-1203.0	JG-06	-907.8
JG-44	-904.8	JG-24	-1274.9	JG-44	-873.9	JG-19	-1304.1	JG-40	-938.5
JG-08	-1186.1	JG-08	-1297.7	JG-11	-1026.5	JG-26	-1673.3	JG-38	-1288.5
JG-06	-1223.3	JG-36	-1469.7	JG-04	-1669.0	JG-21	-2183.4	JG-46	-1475.7
JG-46	-2725.7	JG-23	-2020.1	JG-03	-1850.7	JG-42	-2202.6	JG-13	-1652.1
JG-01	-3034.7	JG-17	-2347.7	JG-02	-3682.2	JG-07	-2742.3	JG-B0	-2539.8
Standard error SCA: 756.5									

Remarks: L: Line, T: Tester, SCA: Specific Combining Ability

JG-40, JG-38, JG-46, JG-13 and JG-B0 with tester of JG-T37.

The research results showed that the values of grain yield were positive and negative. Positive means that the crosses (hybrids) are better than the negative ones (even have the same traits). A negative value means that the crosses (hybrids), which have the same traits, are inadequate compared to the positive ones (Bucheyeki et al., 2017; Choudhary et al., 2018; Khan et al., 2020).

The specific combining ability values in plant height ranged from -35.1 to 19.6. These results were similar to the research by Dufera et al. (2018) and Liu et al. (2018), in which the line x-tester analysis on plant height was negative and positive. Meanwhile, the specific combining ability values in ear height ranged from -26.6 to 17.4. These results were similar to the research by Rahman et al. (2013), in which the effects were negative and positive. If the plant height is too high, it will quickly collapse. Also, if the ear is too high, it will not only easily collapse but also bring pressure on the plant during seed development and ear maturity process due to the position of the ear being far from the soil surface (Andayani et al., 2018; Assefa et al., 2017). Therefore, optimal condition is required. It may become a consideration in utilizing SCA value, such as using inbred lines with high negative SCA to obtain low plant height and ear, while high positive SCA can be used to assemble variety that has a more elevated position of ear and plant height (Dufera et al., 2018; Konaté et al., 2017).

The specific combining ability values in leaf and tassel length ranged from -12.1 to 18.4. and -7.7 to 7.9, respectively. Meanwhile, in days to tasseling, the specific combining ability values went from -5.1 to 5.5. These results were similar to the research by Andayani et al. (2018) and Assefa et al. (2017), in which the general combining ability values were positive and negative on days to tassel. The specific combining ability values in days to silking ranged from -4.4 to 5.4. These results were similar to the research by Assefa et al. (2017), in which the general combining ability values were positive and negative on days to days to tassel. In days of maturity, the specific combining ability values ranged from -6.2 to 9.1.

The specific combining ability values in ear diameter and length ranged from -0.7 to 0.8 and -2.3 to 2.9, respectively. These results conformed to the research by Assefa et al. (2017), in which the specific combining ability values were positive and negative. Meanwhile, the specific combining ability values in the number of rows and kernels ear^{-1} ranged from -2.2 to 2.6 and -10.6 to 5.5, respectively. These results conformed to the research by Andayani et al. (2018) and Assefa et al. (2017), in which the specific combining ability values were positive and negative.

The specific combining ability values in moisture content at harvest ranged from -3.0 to 1.8, while those in the weight of 100 kernels ranged from -0.008 to 0.011. These results conformed to the research by Andayani et al. (2018) and Assefa et al. (2017), in which the specific combining ability values were positive and negative. The specific combining ability values in the weight of wet ear plant^{-1} ranged from -0.05 to 0.04, while those in the weight of wet kernel ear^{-1} ranged from -0.03 to 0.03.

CONCLUSIONS

The specific combining ability values in grain yield ranged from -3682.2 to 5251.7. Crosses that have positive and high specific combining ability values were lines of JG-11, JG-18, JG-34, JG-01, JG-40, JG-B0, JG-19, and JG-02 with a tester of JG-T00; lines of JG-20, JG-01, JG-03, JG-42, JG-02, and JG-46 with a tester of JG-T14; lines of JG-24, JG-08, JG-23, JG-26, JG-21, JG-07, and JG-06 with tester of JG-T15; lines of JG-38, JG-40, JG-35, JG-36, JG-01, JG-51, JG-17, JG-B0, and JG-08 with tester of JG-T22; lines of JG-07, JG-01, JG-26, JG-24, and JG-18 with tester of JG-T37, which are potential as prospective hybrids that have high productivity at maize seed production in the company system. There were combinations for 9 crosses between inbred lines, and the best testers, including JG-06XJG-T15, JG-51XJG-T22, JG-49XJG-T22, JG-B0XJG-T22, JG-35XJG-T22, JG-38XJG-T22, JG-17XJG-T22, JG-36XJG-T22, and JG-49XJG-37, which are potential as prospective hybrid varieties that have high productivity when planted by farmers. Other traits, both vegetative (plant height, ear height, days to tassel, days to silking, and days of maturity) and generative components (weight of wet ear plant^{-1}, the weight of wet kernel plant^{-1}, ear diameter, ear length, number of rows ear^{-1}, and number of kernels row^{-1}) that have the positive high specific combining ability can be used to determine the selected maize hybrids.

REFERENCES

Akula, D., Patil, A., Zaidi, P. H., Kuchanur, P. H., Vinayan, M. T., & Seetharam, K. (2016). Line x testers analysis of tropical maize inbred lines under heat stress for grain yield and secondary traits. Maydica, 61(1), 3–6.

Ali, M., Kuswanto, & Kustanto, H. (2019). Phenomenon of inbreeding depression on maize in perspective of the quran. Agrivita, 41(2), 385–393. http://doi.org/10.17503/agrivita.v41i2.2022

Andayani, N. N., Aqil, M., Efendi, R., & Azrai, M. (2018). Line × tester analysis across equatorial environments to study combining ability of Indonesian maize inbred. Asian J Agric & Biol, 6(2), 213–220.

Assefa, T., Zeleke, H., Afriye, T., & Otyama, P. (2017). Line × Tester Analysis of Tropical High Land Maize (<i>Zea mays</i> L.) Inbred Lines Top Crossed with Three East African Maize Populations. American Journal of Plant Sciences, 8(2), 126–136. http://doi.org/10.4236/ajps.2017.82010

Bhusal, T. N., & Lal, G. M. (2020). Heterosis, combining ability and their inter-relationship for morphological and quality traits in yellow maize (Zea mays L.) single-crosses across environments. AGRIVITA, Journal of Agricultural Science, 42(1), 174–190. http://doi.org/10.17503/agrivita.v42i1.2089

Bucheyeki, T. L., Tongoona, P., Derera, J., & Msolla, S. N. (2017). Combining Ability Analysis for Northern Leaf Blight Disease Resistance on Tanzania Adapted Inbred Maize Lines. Advances in Crop Science and Technology, 5(2), 266. http://doi.org/10.4172/2329-8863.1000266

Choudhary, R. B., Marker, S., Bhattacharjee, I., & Ramnath. (2018). Combining Ability and Gene Action for Grain Yield and Its Component Traits in Yellow Grained Single Cross Hybrids of Maize (Zea mays L.). International Journal of Current Microbiology and Applied Sciences, 7(8), 1666–1671. https://doi.org/10.20546/ijcmas.2018.708.191

de Faria, S. V., Zuffo, L. T., Rezende, W. M., Caixeta, D. G., Pereira, H. D., Azevedo, C. F., & DeLima, R. O. (2022). Phenotypic and molecular characterization of a set of tropical maize inbred lines from a public breeding program in Brazil. BMC Genomics, 23(1), 54. https://doi.org/10.1186/s12864-021-08127-7

Dufera, T., Bulti, T., & Girum, A. (2018). Heterosis and combining ability analysis of quality protein maize (Zea mays L.) inbred lines adapted to mid-altitude sub-humid agro-ecology of Ethiopia. African Journal of Plant Science, 12(3), 47–57.

Gedil, M., & Menkir, A. (2019). An Integrated Molecular and Conventional Breeding Scheme for Enhancing Genetic Gain in Maize in Africa. Frontiers in Plant Science, 10, 490537. https://doi.org/10.3389/fpls.2019.01430

Jahangirlou, M. R., Akbari, G. A., Alahdadi, I., & Soufizadeh, S. (2021). Phenotypic Traits, Grain Yield and Yield Components of Maize Cultivars Under Combinations of Management Practices in Semi-arid Conditions of Iran. International Journal of Plant Production, 15(3), 459–471. https://doi.org/10.1007/s42106-021-00151-7

Karim, A., Ahmed, S., Akhi, A. H., Talukder, M. Z. A., & Mujahidi, T. A. (2018). Combining ability and heterosis study in maize (Zea mays L.) Hybrids at different environments in Bangladesh. Bangladesh Journal of Agricultural Research, 43(1), 125–134. https://doi.org/10.3329/bjar.v43i1.36186

Kartahadimaja, J., & Syuriani, E. . (2021). Test of Newness Uniformity and Uniqueity 11 Polinela Hybrid Corn Lines. IOP Conference Series: Earth and Environmental Science, 1012(1), 012010. https://doi.org/10.1088/1755-1315/1012/1/012010

Kamara, M.M. Ghazy, N.A., Mansour E., Elsharkawy, M.M., Kheir, A.M.S. Ibrahim, K.M. (2021). Molecular Genetic Diversity and Line × Tester Analysis for Resistance to Late Wilt Disease and Grain Yield in Maize. Agronomy, 11(5), 898. https://doi.org/10.3390/agronomy11050898

Khan, A., Ur-Rahman, H., Ahmad, A., Iqbal, M., Kamal, S., Khan, S., & Bu, J. (2020). Combining Ability Analysis in Sweet Corn, 6(2), 47–52. https://doi.org/10.17140/AFTNSOJ-6-168

Konaté, L., Baffour, B.-A., & Traoré, D. (2017). Combining ability and heterotic grouping of early maturing provitamin A maize inbreds across Striga infested and optimal environments. Journal of Agriculture and Environment for International Development (JAEID), 111(1), 157–173. https://doi.org/10.12895/jaeid.20171.572

Liu, Z., Liu, X., Craft, E. J., Yuan, L., Cheng, L., Mi, G., & Chen, F. (2018). Physiological and genetic analysis for maize root characters and yield in response to low phosphorus stress. Breeding Science, 68(2), 268–277. https://doi.org/10.1270/jsbbs.17083

Murtadha, M. A., Ariyo, O. J., & Alghamdi, S. S. (2018). Analysis of combining ability over environments in diallel crosses of maize (Zea mays). Journal of the Saudi Society of Agricultural Sciences, 17(1), 69–78. https://doi.org/10.1016/j.jssas.2016.01.004

Natol, B. (2017). Combining ability and heterotic grouping in maize (Zea Mays L.) inbred lines for yield and yield related traits. World Journal of Agricultural Sciences, 13(6), 212–219.

Oluwaseun, O., Badu-Apraku, B., Adebayo, M., & Abubakar, A.M. (2022). Combining Ability and Performance of Extra-Early Maturing Provitamin A Maize Inbreds and Derived Hybrids in Multiple Environments. Plants, 11(7): 964. https://doi.org/10.3390/plants11070964

Rahman, H., Ali, A., Shah, Z., Iqbal, M., Noor, M., & Amanullah. (2013). Line x tester analysis for grain yield and yield related traits in maize variety Sarhad-White. Pakistan Journal of Botany, 45(SI), 383–387.

Rani, N., Nirala, R., & Acharya, S. (2018). Diallel analyses and heterosis of some agronomic traits in maize (Zea mays L.). Journal of Pharmacognosy and Phytochemistry, 7(SI), 3189–3194.

Ur Rehman, M., Rahman, H., Iqbal M., Khalil, I.H., & Shah, Z. 2018. Line × Tester Analysis of Early Generation Inbred Lines for some Agronomic Traits in Maize. Sarhad Journal of Agriculture, 34(4): 932-940. http://dx.doi.org/10.17582/journal.sja/2018/34.4.932.940

Yadesa, L. M., Alamerew, S., & Tadesse, B. (2021). Combining Ability Study for Grain Yield and Agronomic Traits of Quality Protein Maize (Zea mays L.) Inbred Lines Adapted to Mid-Altitude Agroecology of Ethiopia. Agro Bali: Agricultural Journal, 4(3), 286–304. https://doi.org/10.37637/ab.v4i3.733